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IU.V. SYDORENKO, PhD (Eng.), Assistant Professor, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Peremohy Avenue, 37, Kyiv, 03056, Ukraine, 03056, ORCID: https://orcid.org/0000-0002-1953-0410, suliko3@ukr.net

M.V. HORODETSKYI, PhD student, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 37, Peremohy Avenu, Kyiv, 03056, Ukraine, ORCID: https://orcid.org/0000-0003-4673-3894, horodetskyimykola@gmail.com

MODIFICATION OF THE ALGORITHM FOR DEFINING POLYGONAL GEOMETRY OF AN OBJECT FOR POLYPOINT TRANSFORMATION

The article discusses a modification of the construction of polygons to display deformation processes using polypoint transformations. The object of polypoint transformations is a straight line, which changes its coefficients when the basis changes. If you need to display a two-dimensional figure, then this figure should be represented as a set of segments, that is, a polygon should be formed. The article presents a method for forming a polygon for further processing using the polycoordinate transformation method.

Keywords: *polycoordinate mappings, polypoint transformations, polygonal geometry, transformation basis, transformation object.*

Introduction

In practice, engineers are often faced with the need to check the technical condition of engineering objects for deformation. This should be done not only to ensure equipment reliability, but also to predict the maximum failure-free operation of some elements and individual structural units. Currently, representatives of other professions, such as doctors, often encounter problems with deformities. During military operations, many need the reproduction of damaged, deformed organs. Sometimes this can save the patient's life. The need to solve problems of deformation modeling also arises when predicting the dynamics of the spread of various contaminants, for example, during the use of chemical weapons, or to understand where a fire will spread during "arrivals", in order to quickly respond to the situation.

One of the methods for solving the problem of deformation modeling is polypoint transformations. The apparatus of these transformations helps to quickly obtain a mathematical model of transformations depending on the consequences of deformation. Each object is represented by a set of points that the user specifies during the operation of the algorithm. These points are the intersection of lines. At the output, you need to get a set of points again that will form the transformed object. But there is a problem in obtaining intersection points due to the fact that the geometry of the object is defined by many straight lines, so there will be many intersection points. And you need to determine which intersection points form the modified object. Modifying the method of specifying an object will allow you to quickly obtain these points.

Analysis of Recent Research

Analysis of recent research Work [1] presents the formulation of the problem and methods for implementing polypoint transformations. The use of these transformations has been developed in the presented objects in various ways, as described in [2].

When working with polypoint transformation, there is a need to get the shape of the object after the transformation. As a result of the algorithm, the output is a set of points that need to be combined into a continuous curve. This can be done in different ways, for example, using a Gaussian interpolation curve, as described in [3].

New options for solving the problem of modeling deformed objects have made it possible to increase the accuracy of calculations of the obtained points. This was achieved through the introduction of new functionality described in [4].

Developments in the further development of multicoordinate reflections have made it possible to solve a number of practical problems, such as calculating the area of a closed contour [5], modeling structural elements of ventilation systems [6], modeling and visualization of deformed organs in plastic surgery [7] and other directions

The effectiveness of the process of displaying deformation through polypoint transformations depends on the way the transformation object is represented. This paper discusses an algorithm for representing the initial object as a set of polygons defined in a certain way, which simplifies the display of the same object after applying polypoint transformations to it.

The purpose of the study is to modify the polypoint transformation algorithm by developing a method for specifying object points and developing a flexible approach based on the use of polygons of a certain type.

Modification of the Polypoint Transformation Algorithm

Political transformations are one of the types of polycoordinate reflections that are used to solve

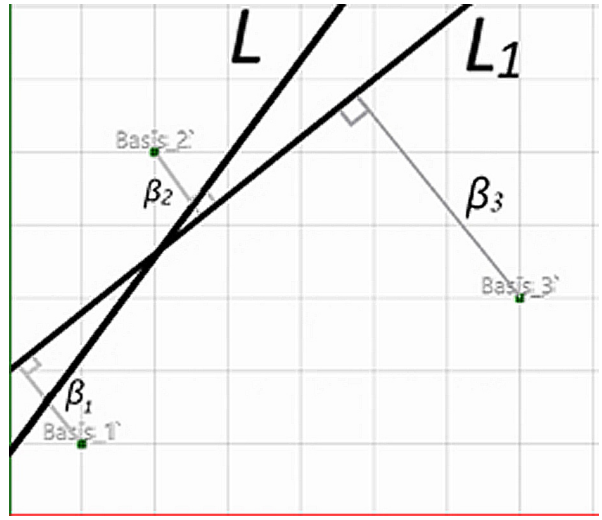

Fig. 1. Political retiring of straight line L_1 using three base points

problems of displaying deformation changes in geometric objects.

The object of deformation during polypoint transformations in two-dimensional space R^2 is a straight line:

$$Ax+Bx+C=0.$$

Let a straight line L_1 with coefficients A_1, B_1, C_1 be given. Solving the problem of multipoint transformations reduces to solving a system of linear algebraic equations, which can be written as follows:

$$A\sum_{i=1}^{p}\frac{X_iX_i}{\beta_i^2}+B\sum_{i=1}^{p}\frac{X_iY_i}{\beta_i^2}+C\sum_{i=1}^{p}\frac{X_i}{\beta_i^2}-\sum_{i=1}^{p}\frac{X_i}{\beta_i^2}=0\,;$$

$$A\sum_{i=1}^{p}\frac{Y_iX_i}{\beta_i^2}+B\sum_{i=1}^{p}\frac{Y_iY_i}{\beta_i^2}+C\sum_{i=1}^{p}\frac{Y_i}{\beta_i^2}-\sum_{i=1}^{p}\frac{Y_i}{\beta_i^2}=0\,;$$

$$A\sum_{i=1}^{p}\frac{X_i}{\beta_i^2}+B\sum_{i=1}^{p}\frac{Y_i}{\beta_i^2}+C\sum_{i=1}^{p}\frac{1}{\beta_i^2}-\sum_{i=1}^{p}\frac{1}{\beta_i^2}=0\,,$$

where X_i, Y_i is the coordinate of the i-th basis node, β_i is the distance from straight line L_1 to the basis X_i, Y_i.

The solutions of the system are three coefficients *A, B, C*, substituting which into the general equation of the straight line, we obtain a new transformed straight line *L*. Fig. 1 shows polypoint transformations of the straight line.

Since with the help of polypoint transformations one can transfer one straight line from one

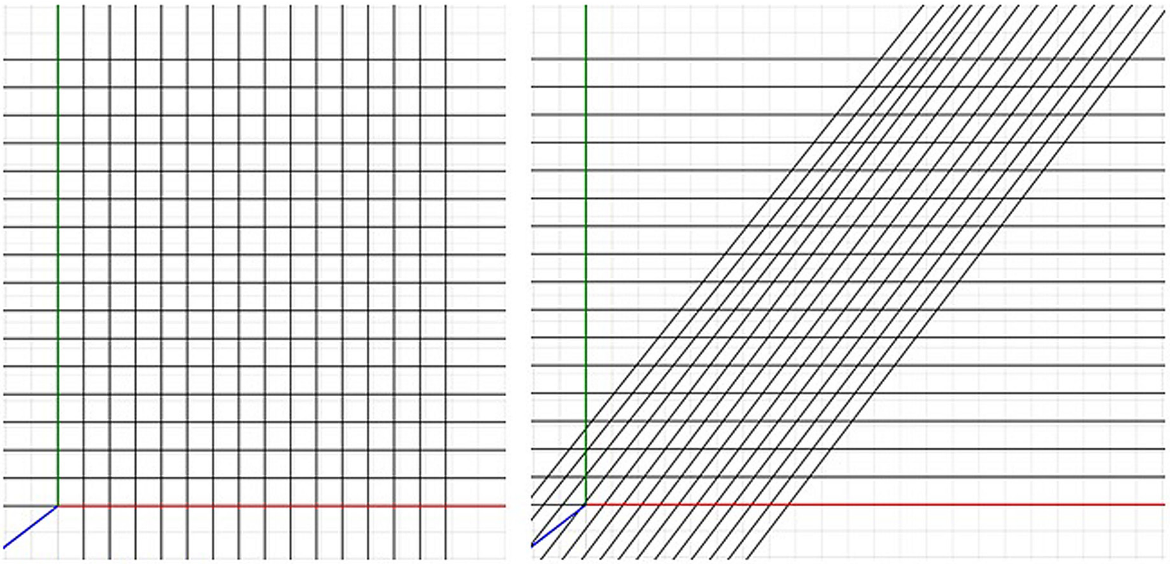

Fig. 2. Grid transformation

basis to another, then several can be done. For example, let's build a grid of straight lines, which is a coordinate grid. This will be a set of orthogonal straight lines with even steps. By controlling the basis points, we obtain a modified coordinate grid, as shown in Fig. 2.

Transformation of arbitrary two-dimensional geometric objects can be carried out in different ways. You can use the same coordinate grid. Display an object on it, split it into points, and then look for corresponding points on the modified mesh. This process is complicated by the fact that the output of the polypoint transformation apparatus is the coefficients of straight lines. That is, some sets of vectors of three numbers. And it is quite difficult to understand where exactly the intersection point of two specific lines will be.

There is another approach that is often used when working with polypoint transformations. Each point of an object is represented by the intersection of two specific orthogonal lines, and then there is no need to keep track of all the intersections of all given lines. Two lines are transferred to a new basis and the point of intersection is found. And so on with each point. But there is a drawback in this approach: since a point is represented by the intersection of two straight lines, the number of calculations doubles, which in turn leads to an increase in calculation time and the use of excessive computer memory.

This study examines a method for defining an object using segments connecting adjacent points, forming a polygon.

When implementing this approach, certain rules must be followed.

Firstly, the segments must be combined, that is, the end of one segment must be the beginning of the next (Fig. 3).

Secondary, this approach requires that the object be locked. That is, the geometry of an object must be specified by combining segments one after another, forming a chain of segments (path), the end of which must always be its beginning.

Geometric Object Transformation Algorithm

Thus, the algorithm for transforming a geometric object will look like this:

1. Set the initial basis of transformations (a certain number of points).

2. We set sequentially the points of the segments into which the object being converted is divided. The end points of the previous segment and the

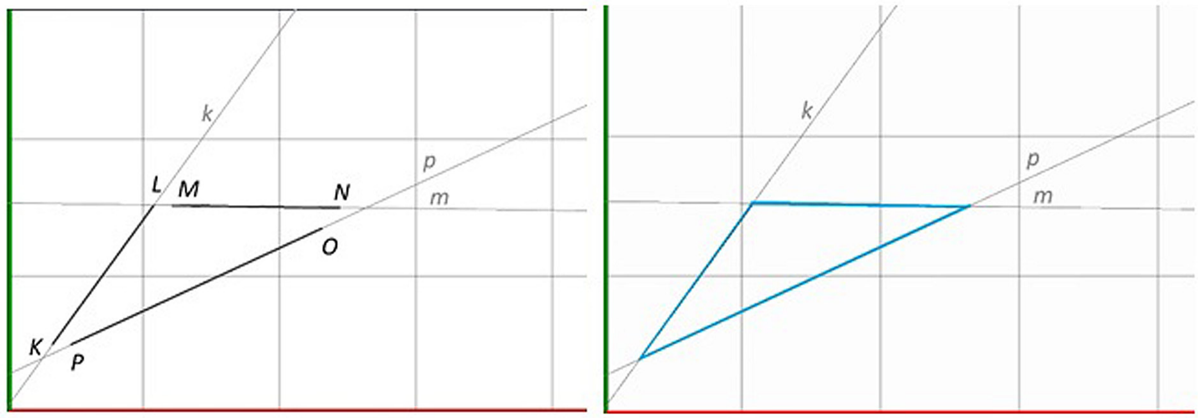

Fig. 3. Object defined by incompatible and combined segments

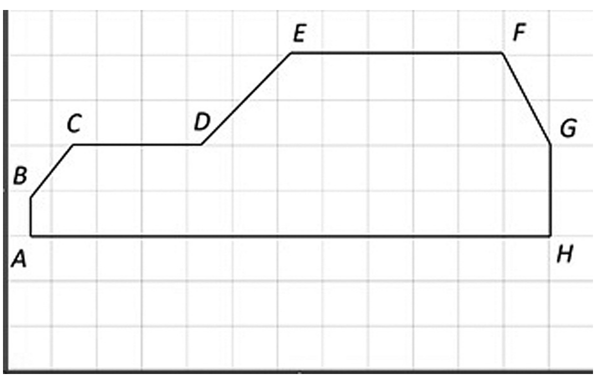

Fig. 4. Example of a closed polygon

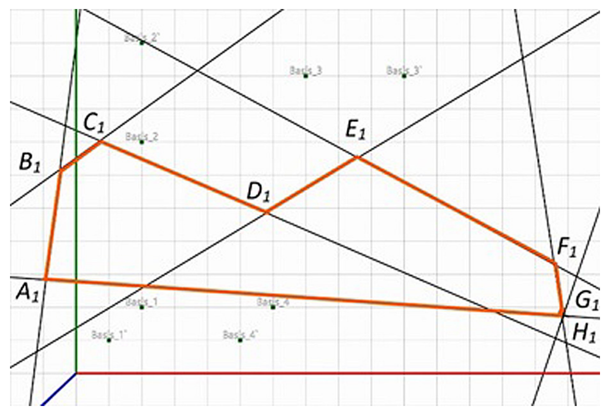

Fig. 5. Position of lines in the transformed basis

beginning of the next are the same, so they do not need to be duplicated.

3. The points fall into a FIFO type queue, the property of which is to process each element in the order it appears.

4. For each pair of sequentially given points, straight lines are constructed, which are the objects of transformations.

5. The original basis is changed by moving the base points.

6. Calculations are carried out using the method of polypoint transformations of new direct positions.

7. At the output we get the intersection points of these lines, which will form the shape of the transformed object.

8. We visualize the found contour using the same order of points as at the beginning of the calculations.

Let's look at this with an example. Suppose you need to define an object in two-dimensional space using segments (hereinafter referred to as edges) for subsequent application of the polypoint transformation method.

To do this, we define each edge sequentially in the direction of following the contour of the object, using two points $(x_i; y_i), (x_j; y_j)$ for each. Having numbered each end of each edge, we obtain a closed polygon "ABCDEFGHA" (hereinafter *AB–HA*) (Fig. 4). Note that the last edge *HA* ends at the beginning of the edge *AB*.

Let's transform the polygon into general lines, apply polypoint transformations, and find the intersection points of adjacent lines in the standard way.

We obtain a new position of the lines in the transformed basis (Fig. 5).

Using the intersection points between adjacent lines (from the list of lines), we form a new

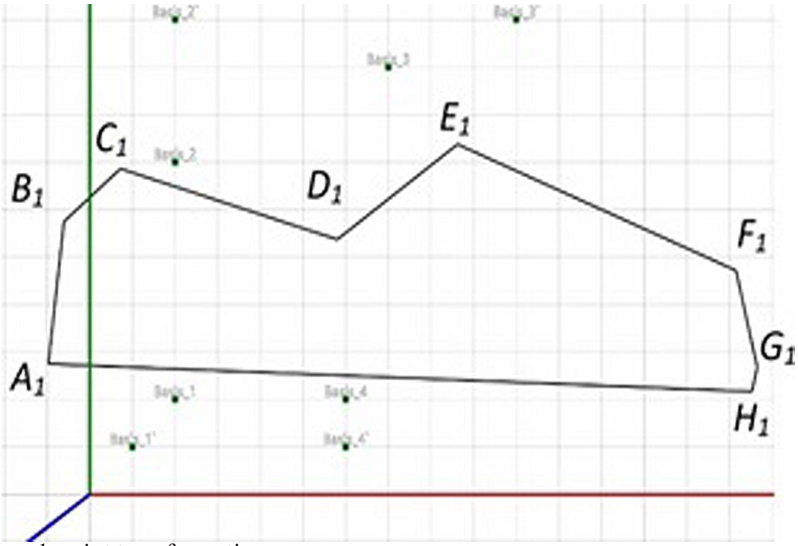

Fig. 6. Polygon after polypoint transformations

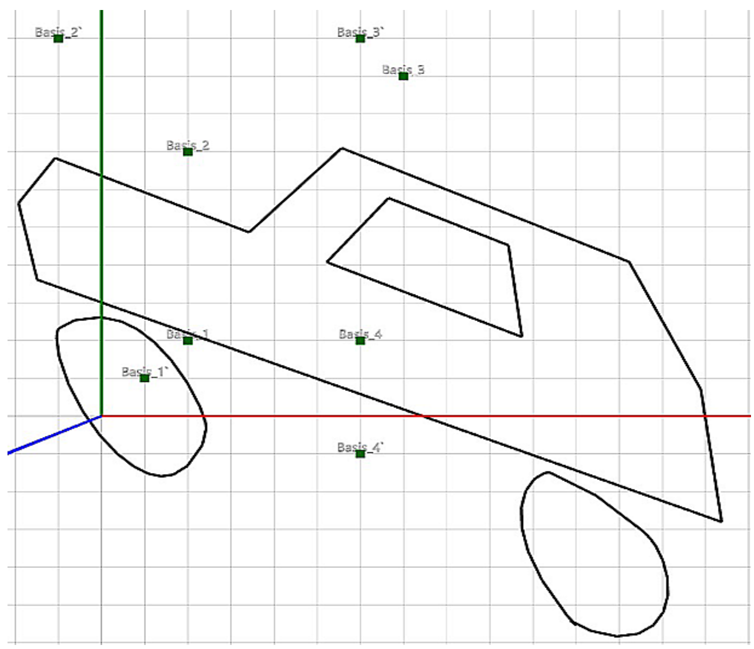

Fig. 7. Object of four polygons after polypoint transformations

polygon "$A_1B_1C_1D_1E_1F_1G_1H_1A_1$" (hereinafter A_1B_1–H_1A_1), which is the prototype of the *AB–HA* polygon (Fig. 6).

Thus, a transformed object was obtained after deformation. The transformed polygon "$A_1B_1C_1D_1E_1F_1G_1H_1A_1$", composed with the same number of edges as the initial polygon "*ABCDEFGHA*", built according to the law of change of basis points.

The same approach can be used for weighted polypoint transformations. To do this, you need to apply another functionality, namely a functionality of this type:

$$S = \sum_{i=1}^{p} m(\beta_i)(\omega_i - 1)^2 ,$$

where $m(\beta_i)$ is a function of the distances to the direct image. For example, let m be inversely proportional to β to an even power. In this case, the object points will be more attracted to the basis points, the closer they are to them. Moreover, the greater the degree, the stronger the connection.

You can also place several objects on the screen and apply the described approach to specifying each object. For example, we set 4 objects in one scene (Fig. 7).

As can be seen from Fig, 7, all four objects were displayed correctly. Moreover, the speed of displaying objects is commensurate with their number and is calculated in fractions of microseconds, in contrast to displaying results without using a polygon.

Conclusions

The problems of constructing two-dimensional objects for further application of the polypoint transformation method to them are considered. An effective method for polygonal definition of an object in two-dimensional space is proposed to preserve the original number of segments in the transformed prototype of the object. The use of the presented algorithm for specifying an object for depicting several objects in one scene is demonstrated.

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Ю.В. Сидоренко, к.т.н., доцент, Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»,
03056, м. Київ, просп. Перемоги, 37, Україна, ORCID: https://orcid.org/0000-0002-1953-0410,
suliko3@ukr.net
М.В. Городецький, аспірант, Національний технічний університет України
«Київський політехнічний інститут імені Ігоря Сікорського»,
03056, м. Київ, просп. Перемоги, 37, Україна, ORCID: https://orcid.org/0000-0003-4673-3894,
horodetskyimykola@gmail.com

МОДИФІКАЦІЯ АЛГОРИТМУ ЗАДАННЯ ПОЛІГОНАЛЬНОЇ ГЕОМЕТРІЇ ОБ'ЄКТА ДЛЯ ПОЛІТОЧКОВИХ ПЕРЕТВОРЕНЬ

Вступ. У наш час інженери вимушені регулярно здійснювати перевірку технічного стану об'єктів для виявлення деформацій, що є важливим для забезпечення надійної, безвідмовної та прогнозованої роботи елементів конструкцій. Проблеми деформацій також актуальні в медицині, де відтворення пошкоджених органів може бути життєво важливим, особливо під час воєнних конфліктів. У розв'язанні задач деформаційного моделювання застосовують політочкові перетворення, які дозволяють швидко отримувати математичну модель перетворень у залежності від наслідків деформацій, використовуючи політочкове представлення об'єкта.

Метою дослідження є розібрати наявні проблеми задання гометрії об'єкта для політочкових перетворень і розробити практичний та гнучкий підхід для їх подолання на базі полігональної геометрії.

Методи. Для виконання проведеного дослідження застосовано метод задання геометрії об'єкта через шлях або полігон, а також метод політочкових перетворень для отримання видозміненого прообразу вхідної геометрії об'єкта.

Результати. У статті досліджуються наявні обмеження щодо задання геометрії об'єкта на двовимірному просторі та наводиться модифікований алгоритм задання геометрії об'єкта для здійснення політочкових перетворень на базі полігонів, а також представлення об'єкта після застосування вказаного методу.

Висновки. За результатами дослідження виявилося, що модифікований алгоритм задання геометрії об'єкта на базі полігонів є зручним, не потребує додаткових обчислень, і за допомогою цього підходу можливо задати геометрію для об'єкта будь-якої складності, придатну для застосування методу політочкових перетворень.

Ключові слова: *полікоординатні відображення, політочкові перетворення, полігон, базис перетворення, об'єкт перетворення.*